Review of Master's Thesis

Student: Király Adrián, Bc.
Title: Design of Guidance, Navigation and Control for Vertical Landing of a Reusable Rocket Booster (id 23838)
Reviewer: Vlk Jan, Ing., DCGM FIT BUT

1. **Assignment complexity** — **more demanding assignment**
   The thesis assignment is, in my opinion, quite challenging as it targets complex topics as modeling and simulation of space vehicles, guidance navigation and control design and implementation of visualization environment.
2. **Completeness of assignment requirements** — **assignment fulfilled with minor reservations**
   The student fulfilled all tasks of the thesis assignment. However, some of them would deserve more attention. Especially the tasks focused on GNC design and evaluation of achieved results.
3. **Length of technical report** — **almost in minimum requirements**
   The thesis is written on 42 pages (from Introduction to Conclusion) and does not meet the minimum requirements for a diploma thesis. The weakest chapters are, in my opinion, Chapters 5, 7 and 8. Chapter 5, Simulating Launch and Landing, does not describe launch and landing but atmosphere model, gravity model and numerical integration method, which is confusing. Chapter 7 Results and Chapter 8 Conclusion are very brief. Evaluating such complex problem as GNC design using only one simulation run and five shortly commented graphs is, in my opinion, not enough.
4. **Presentation level of technical report** — **50 p. (E)**
   The logical structure of the thesis is a bit chaotic. It starts with a concise introduction to the topic and one half of this introduction takes the thesis outline. Following Chapters 2 and 3 are dealing with rocket booster modeling and are, in my opinion, the best parts of the thesis. However, I need to point out that the last two equations in Chapter 2 are not the equations of motion, but they express the forces and moments acting on the rocket booster. Chapter 4 should deal with GNC system design. Still, it only describes the rocket trajectory, some of its sensors as GPS, accelerometers and gyroscopes, propulsion system, which should be part of the chapters dealing with rocket modeling. The last subsection describes the PID controller totally without context or connection to previous subsections.
5. **Formal aspects of technical report** — **70 p. (C)**
   The thesis is written in English and the language is, in my opinion, on a decent level. The thesis typography suffers from some minor flaws. For example, I would not place small tables in the middle of an empty page (Table 4.1) but incorporate them into text.
6. **Literature usage** — **60 p. (D)**
   The student cites 39 literature resources, all relevant to the discussed topic. I would recommend including more resources focused on GNC since it should be the core topic. Some parts of the thesis, specifically Chapters 1 and 6, are poorly cited, in my opinion.
7. **Implementation results** — **60 p. (D)**
   The student created a simulation model of a rocket booster with a GNC system capable of launching and landing vertically using the Matlab/Simulink software. The rocket booster model itself was mainly composed of predefined blocks from Matlab Aerospace Blockset. However, the propulsion model and the GNC system were built by the student. The subsystems dealing with rocket control specifically blocks Control and RCS, are quite confusing since they are not described or explained in the thesis. I would appreciate a more detailed explanation of used GNC algorithms since it is a core topic of the thesis. The visualization of the flight was performed using the CesiumJS library. The user interface is intuitive and straightforward. It shows the 3D trajectory of the rocket booster together with numerical values of rocket states as velocity, altitude attitude and propulsion states. Some of the rocket state values could be visualized graphically, in my opinion.
8. **Utilizability of results**
   The thesis is mainly a compilation of known approaches and algorithms, but it could serve as a starting point for further research in rocket GNC design.
9. **Questions for defence**
   - How did you tune the gains of the PID controller for the roll stabilization.
   - What are the main criteria for switching the guidance modes in block Guidance and how did you choose

these criteria for switching the guidance modes.

10. Total assessment

60 p. satisfactory (D)

The work is, in my opinion, very inconsistent. The parts of the work focused on the rocket model (Chapters 2 and 3) are acceptable and I appreciated the own computation of rocket aerodynamics. However, most of the other parts are somewhat chaotic. The student did not describe Guidance Navigation and Control algorithms at all, making the software realization very hard to understand. Concerning previous findings, I suggest the grade (D).

In Brno 7 June 2021

Vlk Jan, Ing.
reviewer